OH maser envelopes of the “water fountain” sources

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Total Solar Eclipse on 22 July 2009 in Kagoshima

Photo by J. Shukuya
“Water fountains”: collimated fast stellar jets

Very fast (>100 km/s) from AGB/post AGB starts
Very young/short lived (<100 years)
Very drastic (dM/dt>10^{-4}M_{\odot} yr^{-1})
What is the water fountain precursor?

What happens in the final AGB phase?

The \( \text{H}_2\text{O} \) maser jet and the 1612 MHz OH maser envelope driven by the same stellar object?
EVN/Global VLBI observations of 1612 MHz OH masers

Collaboration with
Phil Diamond (JBCA)
Jun-ichi Nakashima, Sun Kwok (Hong Kong Univ.)
Shuji Deguchi (NRO)

• Toward W43A (1994 June - 2007 June)
  – VLBA (BD03, BD20, BI24), Global VLBI (GI01, GI04)
  – Phase-referencing for astrometry:
    successful in GI04 with J1833+0115=LANA (4.72 deg away)

• Toward IRAS 18286-0959 & 18460-0151 (2007 June)
  – EVN (EI09: Ef,Wb,Jb1,Tr,Cm,On25,Mc,Nt,Hh)
  – Phase-referencing for astrometry with
    • J1832-1035 (for IRAS 18286-0959, 0.67 deg away)
    • J1833+0115=LANA (for IRAS 18460-0151, 4.96 deg away)
W43A
OH masers

Spherical expansion with elongation
~9 km/s in L.O.S

Opposite velocity gradient against H$_2$O

Envelope dynamical age
150—300 years
W43A OH shell expansion

- (a few) feature brightness peak proper motions with expansion
- Feature pair statistics: (marginal) positive expansion
  - Radial expansion $\sim 20$ km s$^{-1}$
  - Flow major axis parallel to the H$_2$O jet
  - Contaminated by brightness structure variation

Brightness pattern should be analyzed.
W43A

Dynamical centers within 100 AU (OH-SiO)
Within 10 AU (SiO-H$_2$O in decl.)
(still in checking)
IRAS 18286-0959

A arcs in 3 elliptical patterns

100 AU at 3.1 kpc

H_2O

2006-2007

H_2O and OH

(astrometry)

1612 MHz OH

39.5 km s^{-1}

H_2O ref:
18h31m22.9s, 9387
-09d57'21".449
on 21 April 2008

1612 MHz OH ref.
18h31m22.9s, 9415
-09d57'21".464
on 18 June 2007
IRAS 18286-0959

Point symmetry in position and velocity

H$_2$O/OH dynamical centers within 60 AU
IRAS 18460-0151

High velocity jet (~180 km/s) +
Equatorial/spherical flow (~15 km/s)
Similar scale and velocity in the
H$_2$O and OH regions
opposite velocity gradients

Dynamical centers within 30 AU

Kinematic distance ~6.8 kpc
H$_2$O model fitting distance ~2 kpc
Parameters

<table>
<thead>
<tr>
<th></th>
<th>$V_{\text{jet}}$ (H$_2$O) [km/s]</th>
<th>$V_{\text{envelope}}$ (H$_2$O/OH) [km/s]</th>
<th>$t_{\text{jet}}$ (H$_2$O) [year]</th>
<th>$t_{\text{envelope}}$ (OH) [year]</th>
<th>Separation [AU]</th>
</tr>
</thead>
<tbody>
<tr>
<td>W43A</td>
<td>~150</td>
<td>~30/10</td>
<td>~35</td>
<td>150−300</td>
<td>10−100?</td>
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<tr>
<td>IRAS 18286-0959</td>
<td>~180</td>
<td>~?/15</td>
<td>~15</td>
<td>?</td>
<td>~40?</td>
</tr>
<tr>
<td>IRAS 18460-0151</td>
<td>~190</td>
<td>~10/15</td>
<td>~5</td>
<td>&gt;20</td>
<td>~30?</td>
</tr>
</tbody>
</table>

• Co-location of a **high-velocity collimated jet** and a **low-velocity spherical envelop** within 100 AU.

• Separation between a **high-velocity collimated jet** and a **low-velocity spherical envelop** by > 10 AU?

• Speeds of the **OH envelopes/H$_2$O equatorial flows**:
  ~10−20 km/s ~ $V$(typical AGB envelope
Simultaneous development of a stellar jet and an envelope/torus

- Common sequence of evolution between PPNe and water fountains
- Time lag $\sim 200-300$ years
- Interaction event between a torus followed by a jet on a short time scale
- **Binary system scenario** may produce the interaction event and explain (multiple) discrete mass ejection.
- The interaction event may occur in AGB phase.